Supporting Information

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SI Text

Calculation of Mutual Information. Information theory has been an important mathematical tool to study how the spike train of a single neuron or a population of neurons transmits information about a behavioral parameter. The mutual information (MI) is a measure of the statistical dependency between the behavioral variable (i.e., produced interval, $n = 12$) and a neurophysiological parameter (i.e., the single-trial ramp duration, slope, τ value, etc. . . across the cell type population). Thus, the MI between the behavioral variable I and neurophysiological parameter r can be defined as:

$$MI(r,I) = \sum_{r,I} p(r,I) log_2 \left(\frac{p(r,I)}{p(r)p(I)} \right)$$

where $p(r, I)$ is the joint probability of r and I, and essentially tells us how much extra information one gets from the behavioral variable by knowing the outcomes of the neurophysiological parameter (1). The overall probability $p(r)$ of observing the r value of the neurophysiological parameter was obtained by marginalization: $p(r) = \Sigma_I p(r, I)$. The $p(I)$ for produced intervals was calculated from the behavior of the monkeys during the neural recordings (see Fig. S4).

The joint distribution $p(r, I)$ was computed from a count matrix $C(i, j)$, in which each entry (i, j) is the number of times a j value of the ramp single trial parameter was observed for the interval duration i. Hence, the approximation: $p(r,I) = \frac{c(i,j)}{\Sigma_i \Sigma_j c(i,j)}$.

1. Golomb D, Hertz J, Panzeri S, Treves A, Richmond B (1997) How well can we estimate the information carried in neuronal responses from limited samples? *Neural Comput* 9: 649–665.

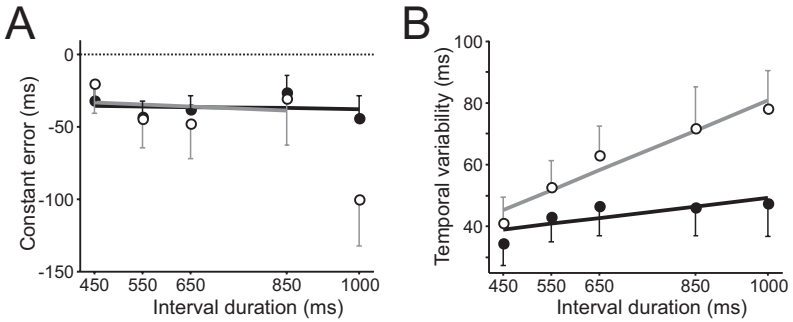

Fig. S1. Timing behavior of the monkeys. (*A*) Constant error (mean ± SEM) as a function of target intervals for the synchronization (filled circles) and continuation (open circles) phases. The linear regression fits between the constant error and interval duration showed slopes close to zero and regression constants around 30 ms, with no significant differences between the synchronization and continuations phase (repeated measures ANOVAs, for slopes: $F(1,772) = 2.84$, $P = 0.092$; for regression constant: $F(1,772) = 2.3$, $P = 0.13$; see *Methods*). Hence, the monkeys were able to produce the target intervals with a small underestimation of around 35 ms across interval durations and task phases. The horizontal line at zero represents perfect accuracy. The straight lines correspond to the best linear fittings, however, for the continuation phase (gray line) the interval of 1000 ms was eliminated of the regression analysis. (*B*) Temporal variability (mean ± SEM) increased as a function of the target intervals for both task phases, following the scalar property of interval timing (Gibbon et al., 1997). The straight lines correspond to the best linear fittings (black: synchronization; gray: continuation).

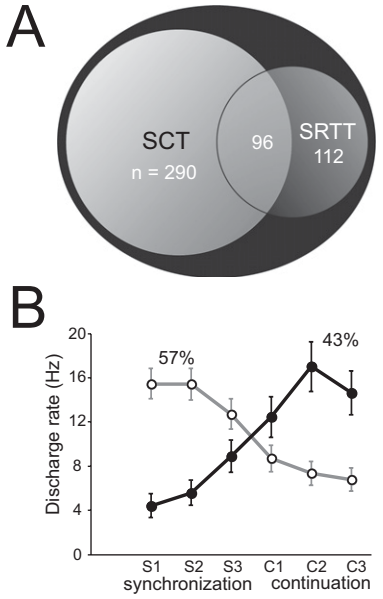

Fig. S2. Analysis of the sequence-related activity during the SCT and SRTT. (*A*) Venn diagrams illustrating the two intersecting sets of phase-related cells during SCT or/and SRTT based on ANOVAs, one for each task, where discharge rate of the neurons was used as dependent variable and the initial and final phase of the tasks were used as factors. The black ellipse denotes the total universe. The areas are proportional to the inset numbers. (*B*) Discharge rate of the phase selective neurons during the sequence of the SCT, with S1–S3 corresponding to the synchronization and C1–C3 to the continuation phase. The mean and SEM of the synchronization-selective responses are depicted as open circles and a gray line, whereas the continuation-selective responses are shown in filled circles and a black line. The percentages indicate the proportion of synchronization- and continuation-selective cells.

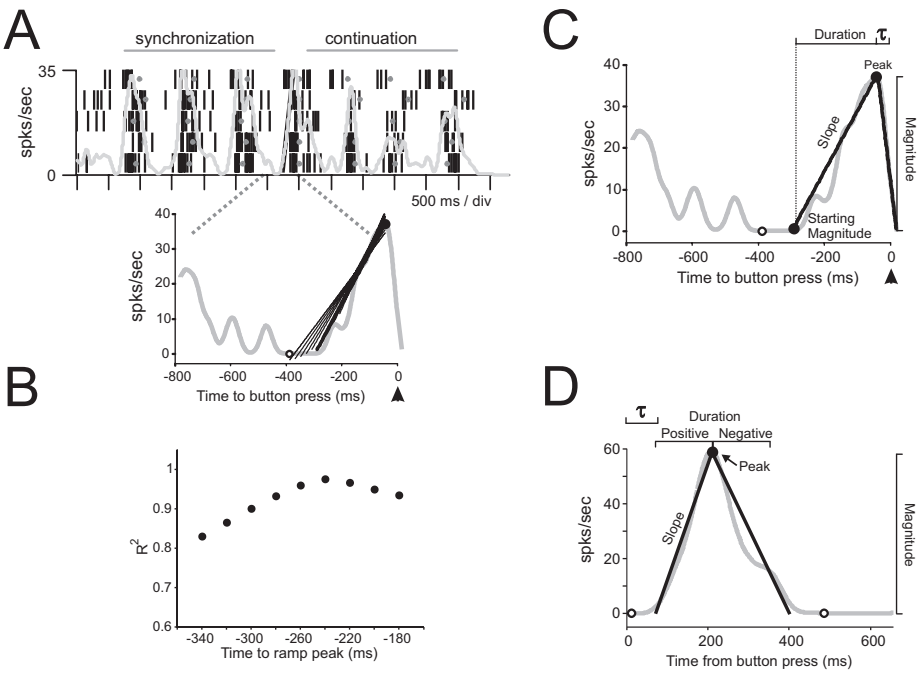

Fig. S3. Iterative algorithm used to find the best regression model to explain the increase or decrease of instantaneous activity over time with respect to a sensory or motor event. (*A Upper*) Raster plot and mean SDF (gray function) of a ramping cell aligned to the first tap of the continuation phase. (*Lower*) The region indicated by the dotted lines in *Upper*, where a series of linear regression functions are displayed, including the best model identified by the algorithm shown as the thicker line. (*B*) Regression R^2 as a function of the time to ramp peak for the example depicted in *A*. (*C*) Parameters that were extracted from the linear regression model for the motor, relative-timing and swinging ramps. (*D*) Parameters that were extracted from the two consecutive linear regression models for the absolute-timing and time-accumulator ramps. Only the neurons that showed more than three significant ramps on the average SDF across interval durations of at least one of the six produced intervals in the SCT sequence, where the significant ramps showed consistent positive or negative slopes, were studied further. Subsequently, the ramp algorithm was performed for each trial on these neurons. This second step was carried out with three purposes: (*i*) To eliminate the cells that showed phasic activity with different response onset latencies across trials, which can produce an artificial activity ramp on the average SDF. (*ii*) To perform the ANOVAs on single trial ramps that allowed the classification of motor, relative-timing, and swinging cells for neurons with consistent responses to the second button press; or the classification of absolute-timing or time-accumulator cells for neurons with consistent responses to the first button press. (*iii*) To carry out the regrouping of single trial ramps as a function of the produced interval and performed the subsequent population analyzes.

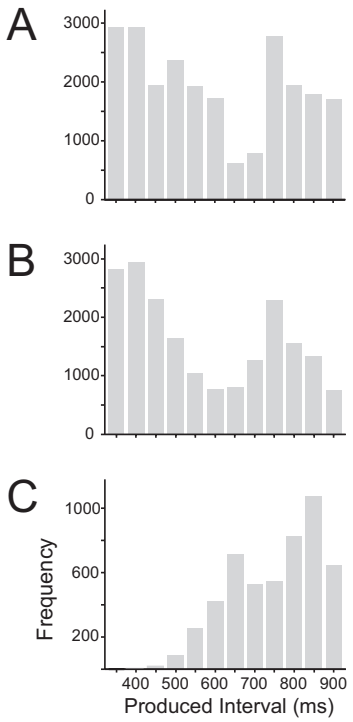

Fig. S4. Distributions of the duration of produced intervals during the synchronization (*A*) and continuation (*B*) phases of SCT, and during the SRTT (*C*) for both monkeys.

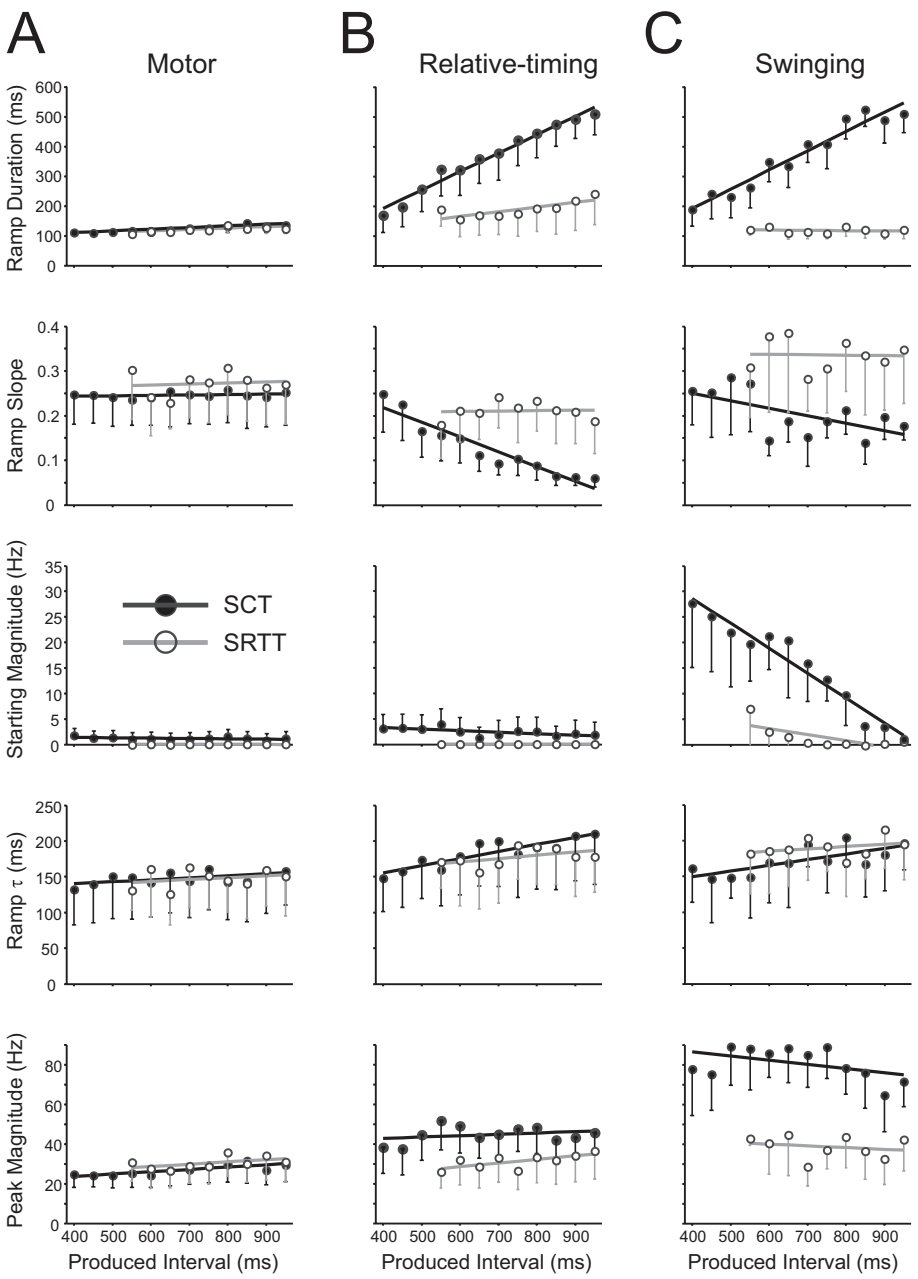

Fig. S5. Mean (± SEM) of the ramp duration, slope, discharge rate at the beginning of the ramp (starting magnitude), τ value, and peak magnitude as a function of the produced interval. (*A*) Motor cells. (*B*) Relative-timing cells. (*C*) Swinging cells. Lines correspond to linear regression fits. SCT: filled circles, black line; SRTT: open circles, gray line.

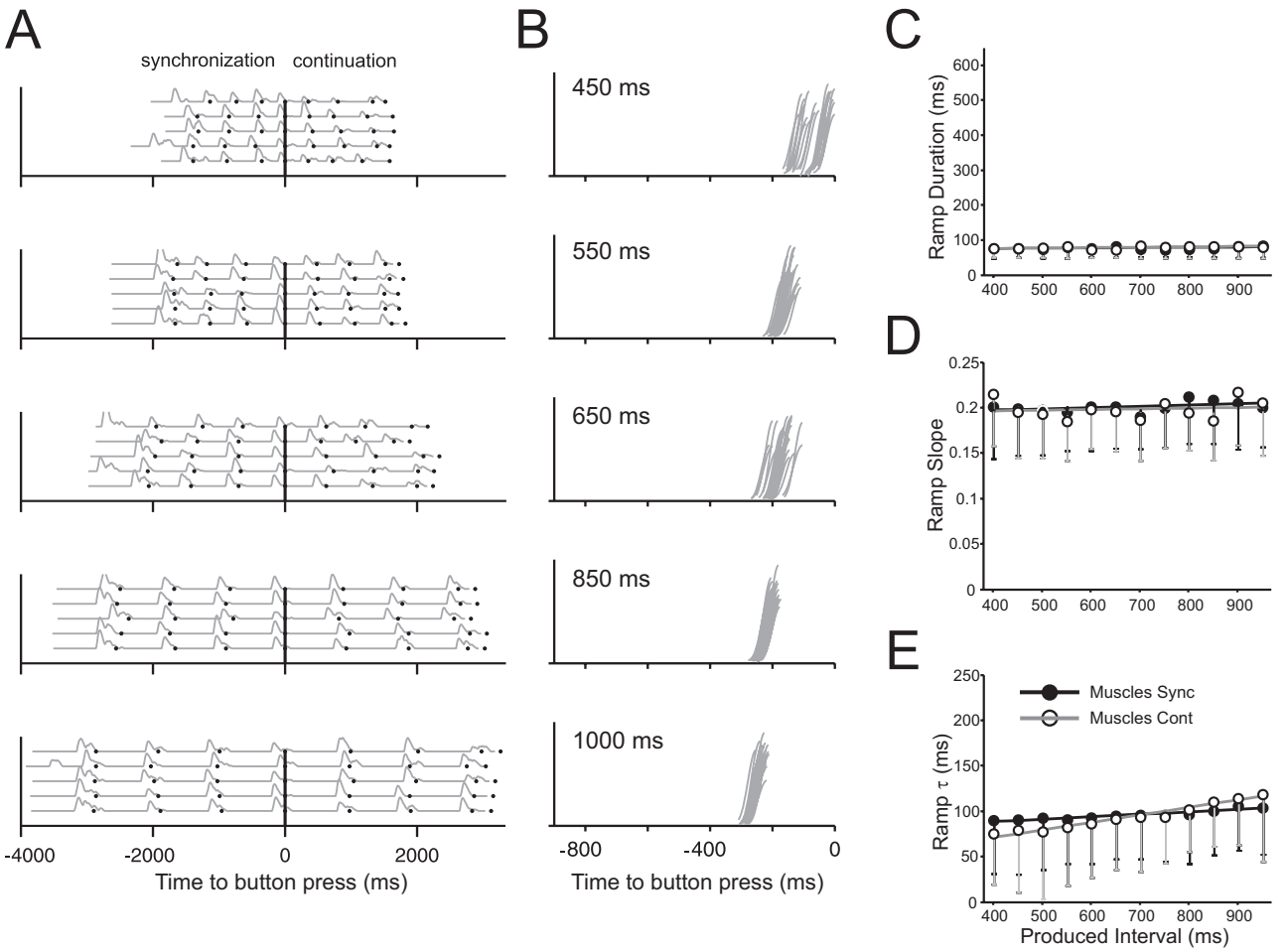

Fig. S6. (*A*) Raster plot for the EMG activity of the *triceps brachii* of monkey 2 during the SCT aligned to the first continuation tap. Same conventions of Fig. 2. (*B*) The corresponding ramps of the *triceps brachii* EMG detected by the iterative algorithm. Ramp duration (*C*), slope (*D*), and τ value (*E*) as a function of the produced interval for the population of EMGs with significant ramping activity. The EMG was recorded in the same two monkeys in separate sessions from the neural recordings using intramuscular, multistranded, teflon-coated wire electrodes. EMG activity was recorded bilaterally in the following muscles for both monkeys: triceps brachii, biceps brachii, deltoideus (anterior, middle, and posterior), extensor digitorum communis, extensor digitorum 2,3, flexor digitorum sublimis, rhomboideus major, trapezius, pectoralis major, and latissimus dorsi.

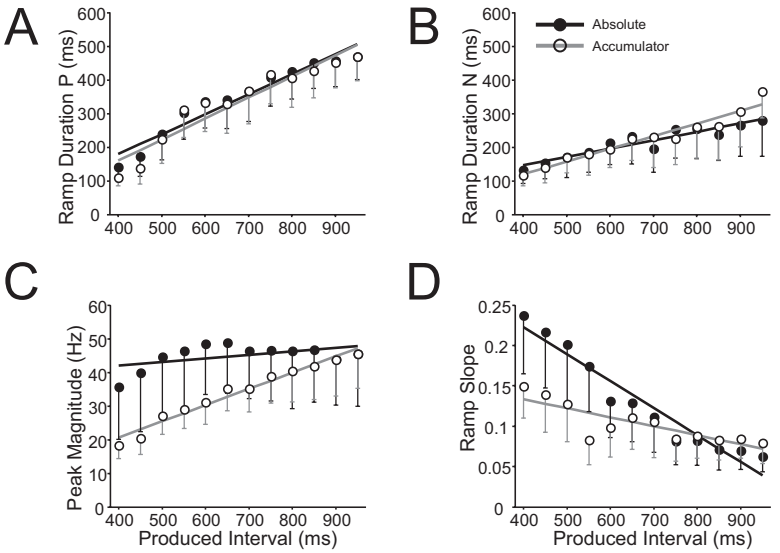

Fig. S7. Mean (± SEM) of the ramp duration for the positive ramp (*A*), the ramp duration for the negative ramp (*B*), the peak magnitude (*C*), and the slope of the positive ramp (*D*) as a function of produced interval, for absolute timing (filled circles, black line) and time-accumulator (open circles, gray line) cells.

Table S1. *P* values and χ^2 for the Kruskal–Wallis tests performed for ramp duration, slope, starting magnitude, peak magnitude, or Tau value as depending variable and using the produced interval as factor

	Duration		Slope		Starting magnitude		Peak magnitude		Tau value	
Cell	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2
Relative-timing	0	1138.8	0	847	0.06	19	0	147.5	0	82.5
Swinging	0	150.3	0	38.1	0	76.9	0	32.6	0.02	22.5
Motor	0.09	16.1	0.105	17.1	0.79	7.07	0	44.8	0.001	24.9
Muscles synch.	0	39.8	0.23	13.9					0.004	33.9
Muscles cont.	0	69.9	0.006	32.8					0	226.6

Kruskal–Wallis tests are less sensitive to unequal sample sizes. Starting magnitude is defined as the discharge rate of the cells at the beginning of the climbing activity. These values are shown for the relative-timing, swinging and motor ramps, as well as for the muscular activity during the synchronization and continuation phases separately.

Table S2. *P* values and χ^2 for the Kruskal–Wallis tests performed for Ramp duration, slope, peak magnitude, or Tau value as depending variable and using the produced interval as factor

	Absolute-timing		Time-accumulator	
Ramp variable	*P*	χ^2	*P*	χ^2
Duration positive	0	1530.6	0	966.4
Duration negative	0	447.3	0	486.9
Tau value	0	158.1	0	175.4
Slope positive	0	1041	0	558.9
Peak magnitude	0	176.8	0	771.2